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Performance Centered Maintenance as a core policy in strategic maintenance control

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Abstract

Rolling stock maintenance in the Netherlands traditionally is performed on several levels of complexity and therefore on levels of non-availability and cost. The challenge in optimizing performance and cost of rolling stock maintenance is to integrate the policy on maintenance concepts, maintenance locations and maintenance intervals (what, when & where). NedTrain as a subsidiary of the Netherlands Railways is developing and implementing this improved concept of maintenance.
On one hand maintenance concepts are being improved based on the philosophy of Risk Based Maintenance, with customer demands on risks regarding safety, reliability, availability and cost as a basis for maintenance renewal. On the other hand - during analysis of current maintenance concepts and risk based improvements – modularization of maintenance tasks is taken into account leading to possibilities to perform these tasks on a lower complexity level, during natural non-availability moments of train sets (off-peak hours in daytime or at night) in local depots instead of larger workshops.
With this maintenance policy "Performance Centered Maintenance", performance improvements and cost reduction are being achieved. New strategies arise for investments in depots, train equipment (e.g. Real Time Monitoring) and training of mechanics.
In this document a general overview and first results will be given of the approach.

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Keywords: maintenance, performance, risks, strategies, rolling stock

1. Introduction

NedTrain is the part of NS Group, in the Netherlands responsible for the cleaning, maintenance & service, and overhaul of rolling stock and components. NedTrain works 24/7 on ensuring that all trains are safe and reliable to operate, at the lowest possible cost. NedTrain's approximately 3,000 employees manage to maintain an approximately equal number of cars. Figure 1 shows how their tasks are divided, and we explain this as follows.

- Daily maintenance takes place at 35 service locations. Thorough cleaning of inside and outside, safety inspections (clearly specified for each type of stock), and minor repairs where necessary.
- Short-term maintenance is carried out at three workshops for domestic traffic, and one workshop for international traffic. All 750 electric multiple units (EMUs) operated by NS are withdrawn for compulsory maintenance and inspection after 50,000 to 90,000 km, or 80 to 135 operating days of running service. This short cycle maintenance includes check-ups to and replacement of brake linings, wheel axles, pneumatic components, filters, oil inspections, and exchange of parts that reached replacement age. All workshops allow for easy access to the roof and under-floor equipment. It is of course important that all cars are returned to operation as soon as possible.

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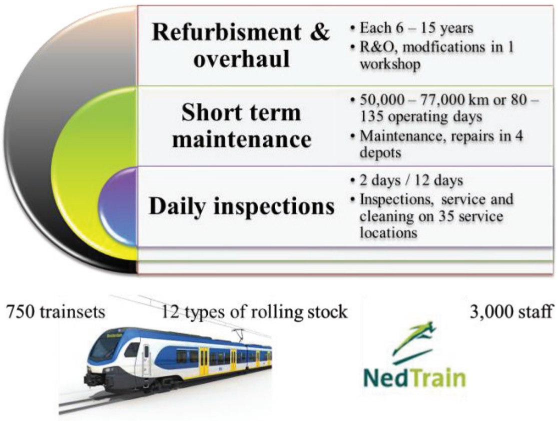

Fig. 1 NS/NedTrain maintenance logistics

- Refurbishment and modernization. Rolling stock requires long term maintenance when the train has reached half of the operational life. This includes maintenance work on the electrical, mechanical and hydraulic technology. Additionally, work on the train body is performed, both on the inside and on the outside of the train. Depending on the relevant functional and/or statutory requirements, maintenance work may involve anything from making small adjustments to full modernization. Work may include the retrofitting of air conditioning (HVAC), toilet systems with bioreactors, passenger information systems and new signaling systems.

Rolling stock maintenance traditionally is treated as static, based on fixed terms (time, mileage), supplier maintenance guides, fixed depots with given equipment, workmanship and hierarchy of maintenance complexity. All this in an environment of oligarchy with low challenges on improvements.
This maintenance structure is drastically changing in the Netherlands over the last 10 – 20 years, affecting NedTrain in a positive way in terms of organizational structure, mentality, focus on improvement of rolling stock performance and cost.

As a spin-off NedTrain started implementing new philosophies on maintenance: Performance Centered Maintenance (PCM), based on known principles of Risk Based Maintenance (RBM), a concept well known in other industries, but rather new for rolling stock: in addition also taking into account maintenance location strategies.

The next chapter 2 will describe the PCM-approach in general. In chapter 3 an elaboration of the approach is given in 2 examples. This document is ended with some first conclusions on this approach.

2. Performance Centered Maintenance in 4 steps

PCM, based on RBM, is a way of looking at maintenance in such a way that optimal maintenance is executed given customer (rolling stock operators) demands on performance and cost. Since customer demands are not static but dynamic given the time of the year, economic climate etc., maintenance will also be dynamic.
In this chapter we will present a 4 step approach to deal with this dynamic maintenance concept.

2.1. Step 1: agree on risks

Risks on safety are obvious, but there are also risks on reliability loss, availability, image, quality and cost. In fact, the responsibility for these risks aspects is not NedTrain's, but primarily the Transport Operator's. The first question to be asked is: "what risks is the operator prepared to accept"?. Knowing these risk limits NedTrain is able to set up and modify the necessary maintenance policy. This first step might be obvious, but is hard to take in practice.

- In general, rolling stock performance, and thus maintenance, is contracted on a high level, in terms of 'number of safety issues', 'number of unavailable train sets', 'number of unplanned depot entries'. These KPI's are mostly interrelated, but are all these relations known? And what does this mean in terms of a risk matrix or other methods such as Fine and Kinney (F&K) [1])? Is safety equally important as availability or reliability?
- How strong is the gut-feeling on safety, related to image? When transforming the number of safety issues into number of fatalities, as is used in the F&K-method, it will lead to a given acceptance level. When - unfortunately - an incident occurs, public opinion and politicians will try to increase this safety level without accepting a higher cost level for maintenance.

In practice we work with an officially excepted safety risk matrix between the operator and NedTrain, combined with the agreed performance criteria and cost, whilst improving the risk matrix on management level. Important point is that there is a mutual understanding of the starting point of maintenance.

2.2. Step 2: to train Maintenance Engineers

In our opinion one of the reasons many RBM approaches fail, is because of a 'jumping to expensive software tools', without knowing exactly what to do with it. For this reason we started with developing our own tools in Excel, and training our maintenance engineers (in the specific NedTrain case we consider at least two roles in maintenance: the maintenance engineer, responsible for the cost efficient and effective 'maintenance manual' of a train type, and the reliability engineer, responsible for the analysis and improvement of the performance of a certain train type).
Although time consuming, it gave us the correct insights in the details of FMECA (Failure Modes, Effects, Criticality Analysis), of maintenance interval optimization and rolling stock performance improvement, paying off in quick wins on performance.

2.3. Step 3: Prioritize

A RBM-approach tends to be time-consuming. To complete the analysis, technical data need to be gathered on each component involved in a certain function, its failure rate, understanding of its function, failure mechanisms, consequences of failures in terms of risks, optimal maintenance strategy etc. In one function of a system several hundred components might be involved, taking it months of study, capacity of engineers and mechanics.

In our approach we start with answering the question what systems and subsystems, which function losses contribute most to performance, cost and risks, thus creating a natural order of handling. In case of cost, figure 2 shows a typical order.

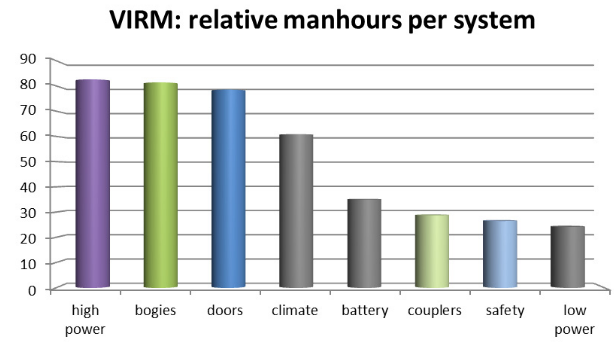

Fig. 2 typical use of manpower for short term maintenance, per system

When more than just cost is considered, figure 3 shows that another order of systems will be applicable.

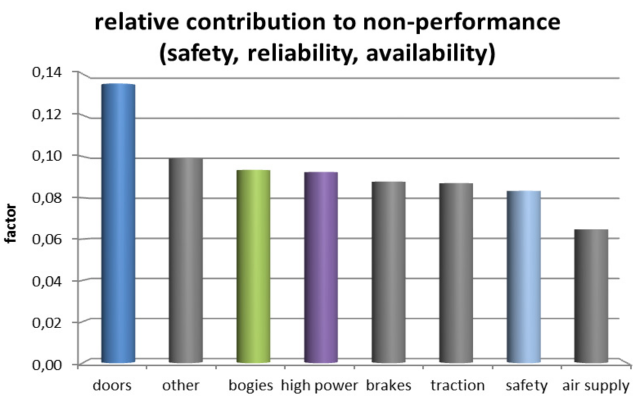

Fig. 3 typical distribution of system influence on performance

An analysis per system is not fully performed, but we prioritize to the highest expected impact. Consequence of this prioritization is that the analysis per system or per function won't be complete yet. This is unfortunate but more important is to get short term results giving energy and motivation to proceed with less important subsystems.

2.4. Step 4: take the operation plan into account

When preparing maintenance for new train types, decisions are made on work to be done during daily inspections, short term maintenance and overhaul. This distribution of work will normally be done based on expertise, available equipment and tooling.

While performing an PCM-analysis on maintenance, the question may be posed whether earlier choices are still valid. Could it be possible for instance to gain on availability by inspecting more frequently during natural off-service periods rather than during planned maintenance in a depot? When utilizing a depot, train sets normally will be unavailable for approximately 60-70 hours, influenced by inspection based maintenance and successive unplanned maintenance. For this reason, during the analysis we assess the possibilities of rescheduling work to other locations.

3. Elaboration: examples

With the PCM-concept running for 2 years, first results are available and very promising for the future. We present two of these successes as a demonstration of the power of Risk Based Maintenance. The first success demonstrates the use of an adequate FMECA-analysis based on functions to get to optimal maintenance schedules.

3.1. Door system Sprinter Light Train (SLT)

Sprinter Light Train (SLT) is a new train type built by Bombardier and Siemens, and in service since 2009.
We analyzed the door system because, after having done step 1 and 2 in the PCM-method, we concluded the door system to be the least performing system. Starting point for further analysis were the functions of the door systems. The door functions were derived from (inter)national standards on rolling stock functions [2]:

- Function D - Provide access and loading

And related to a specific area of interest, the end switches:

- DBL - Signal all external door closed and locked state
- DBB - Release external doors

After a complete analysis of functions and function losses related to the door system, we concluded that the end switches of the deployable step were critical in their performance and cost. The current maintenance rule was to inspect all switches each year. This being time-consuming since access to this switch is hard.
We investigated the switches and found out that mechanical failure was dominant. Electrical failure was considered to be random, and hard to improve by planned maintenance.

Given the two relevant functions of the end switches we analyzed the following function losses:

Function losses (‘retracted’-switch):

A. Switch falsely indicates no safe situation to drive (critical!)
B. Switch indicates safe situation while step is not fixed (non-critical, step will stay in place)

Function losses (‘deployed’ switch):

C. Door PLC fails, indicating safe situation (non-critical, door can manually be locked)
D. Step switch falsely indicates deployed step (non-critical, step will proceed to deploy when loaded).

We concluded that function loss A was the only critical function loss. This meant that the switch lever isn’t getting high enough when a notch (5) is rotating, as indicated in figure 4:

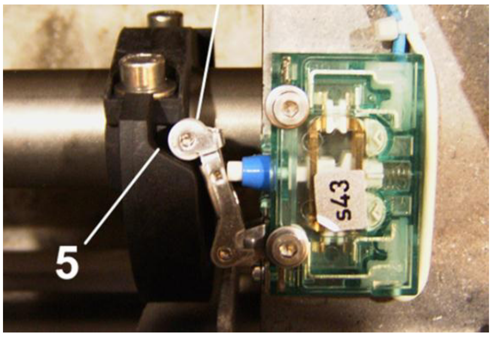

Fig. 4 end switch with notch

We considered the following causes:

1. End switch defect due to wear
2. End switch position changed due to wear
3. End switch defect due to moist or dirt

We concluded that wear and deterioration due to moist and dirt are time dependent and will have a low deviation between the separate switches. Inspection of the switches within a certain sample is adequate. The sample rate was calculated and implemented, resulting in yearly 500 hours less manpower.

3.2. Brake pad maintenance related to maintenance location

Brake pads on our VIRM train type (fig. 5) traditionally have an inspection each short term maintenance (75,000 km or 112 operating days). Apart from the analysis on correct rejection levels on a statistical basis [3], there is a benefit achievable when taking the production model into account.
With only short term maintenance as a regular way of performing maintenance, one would choose in case of a certain type of bogies to set the rejection level at a brake pad thickness of 19 mm (19 mm rejection level derived from a technical minimal thickness combined with an estimated loss of material during two inspection intervals). After a thorough analysis, as a pilot we introduced the principle of modular

Fig. 5 VIRM train set

maintenance: maintenance with a frequency of one third of the regular intervals, work split up in batches of shorter duration, work with longer duration planned in weekends, thus optimizing availability. With this new approach we were able to reduce the reject level to 12 mm, saving manpower and use of brake pads.

3.3. Further initiatives

The examples given in 3.1 and 3.2 are typical for the PCM approach developed at NedTrain. They bring us to the question whether more improvements are to be implemented using PCM. On the short term the earlier mentioned quick wins are key to success. Valuable next steps are further integration of production plans and PCM, with the following suggested rules for our approach:

- Perform short term maintenance on service locations unless..
- ... unless specific equipment is necessary (e.g. wheel lathe, bogie exchange)
- ... unless specific knowledge lacks on service locations
- Maximize planned activities in depots. Perform inspections on service locations and schedule consequent work on a next depot entry
- Use Real Time Monitoring – if possible – to simplify or skip inspections on service locations

In summary, PCM offers a new approach in setting up, control and implementation of maintenance manuals. Not only by introducing risk based and quantitative analyses on rolling stock, but also by active participation from and collaboration with executives, thus optimizing risks, performance and cost.

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